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# The H-Metaphor as a Guideline for Vehicle Automation and Interaction

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## Overview

Good design is not free of form. It does not necessarily happen through a mere sampling of technologies packaged together, through pure analysis, or just by following procedures. Good design begins with inspiration and a vision, a mental image of the end product, which can sometimes be described with a design metaphor. A successful example from the 20th century is the desktop metaphor, which took a real desktop as an orientation for the manipulation of electronic documents on a computer. Initially defined by Xerox, then refined by Apple and others, it could be found on almost every computer by the turn of the 20th century.

This paper sketches a specific metaphor for the emerging field of highly automated vehicles, their interactions with human users and with other vehicles. In the introduction, general questions on vehicle automation are raised and related to the physical control of conventional vehicles and to the automation of some late 20th century vehicles. After some words on design metaphors, the *H-Metaphor* is introduced. More details of the metaphor's source are described and their application to human-machine interaction, automation and management of intelligent vehicles sketched. Finally, risks and opportunities to apply the metaphor to technical applications are discussed.

The metaphor might, within certain limitations, open up new horizons in vehicle automation.

## Questions on vehicle automation at the start of the 21st Century

Scientific and technological progress offers benefits that our ancestors could only dream of. Machines can make our lives easier - as vehicles, they help us to move faster and further. Advances in hardware and software power hold promise for the creation of more and more intelligent vehicles. At the beginning of the 21st century, vehicles like modern airplanes are already so sophisticated, that they can operate autonomously for extended periods (Figure 1). Prototype cars utilizing machine vision (Figure 2) can, under limited circumstances, drive fully autonomously on public highways (Dickmanns, 2002).

**Figure 1 – Uninhabited Aeronautical Vehicle**

But advances in hardware and software do not automatically guarantee more intelligent vehicles. More importantly, intelligent or autonomous vehicles do not necessarily mean progress from which humans can really benefit. In aviation, a forerunner in technology through the 20th century, the development towards highly automated and intelligent aircraft led not only to a reduction of physical workload, but also to severe problems like mode confusion, human-out-of-the-loop, and many more (Billings, 1997; FAA, 1996; Wiener, 1989). This creates what Bainbridge calls the ‘irony of automation”, where "*by taking away the easy parts of his tasks, automation can make the difficult parts…more difficult*" (Bainbridge, 1987).

How should we apply the "lessons learned" from late 20th century cockpit automation to the design of future vehicles? How do we balance between exploiting increasingly powerful technologies and retaining authority, with clear roles between humans and automation? Will human factors (inter-) face lifting be sufficient, or do we have to significantly change how the automation is structured and behaves as well as how it looks and feels? If we are technically capable of building more complex systems, how do we structure them so that they can easily be understood and operated? Norman (1990b) points towards a solution:


**Figure 2 – Autonomous Automobile (Dickmanns, 2002)**

*"The solution will require higher levels of automation, some forms of intelligence in the controls, an appreciation for the proper form of human communication...".*

How do we think about higher levels of automation beyond the concepts of 20$^{th}$ century Artificial Intelligence? Why does conventional automation not provide this proper form?

## Control of physical movement: Conventional Vehicle

On an abstract, functional level, all vehicles are controlled in a similar fashion, as described in various functional models, e.g. McRuer, Graham, Krendel, & Reisener (1965); Rasmussen (1983). Strongly simplified, the operator takes in information from the environment and processes it in terms of deviations from desires or goals. He then moves the effectors through various control inceptors with the intent of minimizing any deviations, and monitors the outcome in the environment as well as the feedback from the inceptors (see Figure 3: solid line represents control task).

Experienced operators are often able to reduce the required effort by developing precognitive (McRuer, et al, 1965) or skill-based routines, e.g. Rasmussen (1983), but his/her sensory and processing resources are still limited, e.g. Wickens (1992). Other tasks (e.g. more strategic tasks, dotted line in Figure 3), such as monitoring quantity on a fuel gage/display, have to be kept short in order not to break the actual control loop, e.g. Baron & Levison (1977). Most people have also experienced this limitation first hand by attempting to read a map while driving a car in heavy traffic.

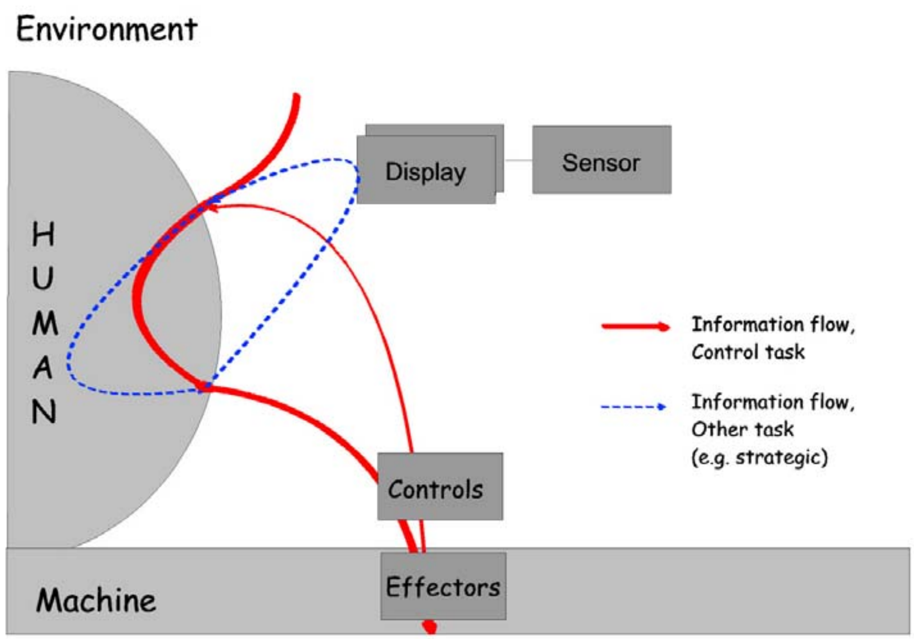


**Figure 3 – Control of Physical Movement**

## Automated vehicles in the late 20th Century

The technical developments of the 20th century, combined with recognition that the demand of constant manual control can create excessive operator workload, resulted in some vehicles being equipped with sophisticated automation.  Figure 4 shows the situation in a late 20th century commercial aircraft.

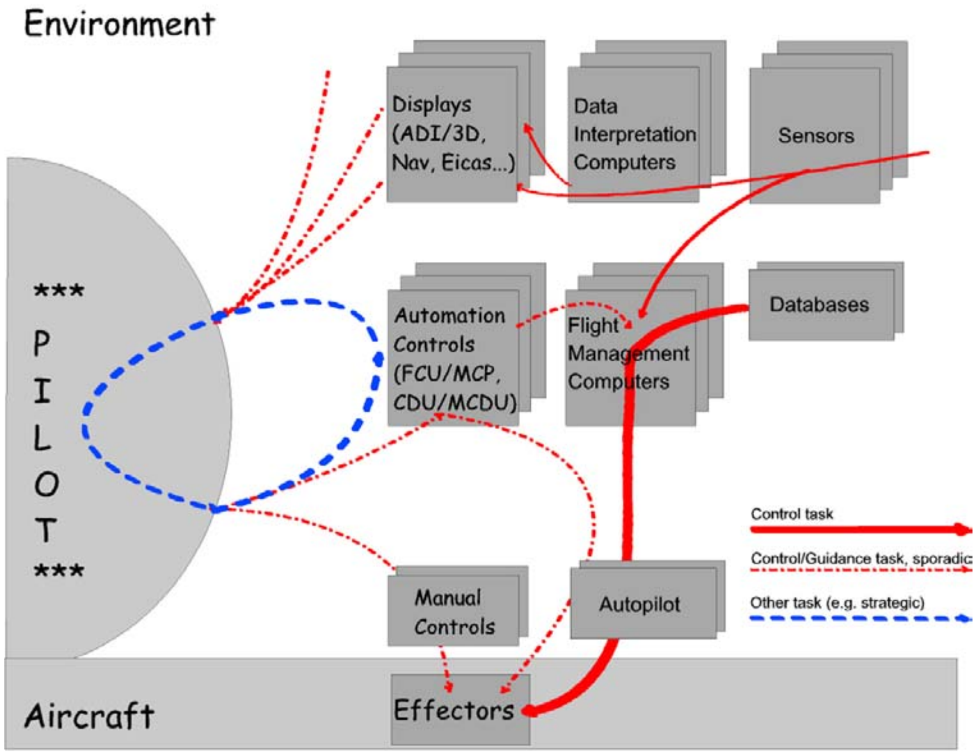


**Figure 4 – Control in a Modern Aircraft**

The operator's main source of information is no longer directly from the external environment, but from a collection of control, performance, and navigation displays (information automation, (Billings, 1997)).  The control inceptors no longer have reversible linkages to the control effectors. In some implementations (e.g. Airbus aircraft), the primary control inceptors are simple spring loaded devices providing feedback only about the pilot's own inputs. No other information such as the actions of other crew members or the ability of actuators to follow the inputs are provided. Much of the time, these highly automated vehicles are not manually controlled.  Rather, they are commanded at a fairly abstract level through various controllers such as the autopilot/autothrottle for heading/altitude/airspeed.  Every time a new functionality was desired, a new box was added, often without regard for an overall cockpit concept. Wiener (1989) calls this "one-box-at-a-time" automation.

Flight management systems (FMS) were developed that automated the majority of required control tasks necessary to perform complete flight segments (e.g. route following or fully automatic landings) and even complete flights, excluding take-off. However, vehicles may be operated with or without the FMS fully engaged for all control axes, and other auto-flight systems sometimes take precedence over FMS input (e.g., mode reversion). As a result, the automation behavior can appear unpredictable to the operator, and is subsequently prone to cause “human error”. Pilots are often quoted as saying, "What is it doing now" (Wiener, 1989) and "How in the World Did We Ever Get into That Mode?" (Sarter & Woods, 1995). The role of the pilot becomes one of supervising and monitoring the automation without direct physical involvement, leaving him/her ill-primed to both recognize an issue in the first place (Satchell, 1993), and to intervene if necessary.

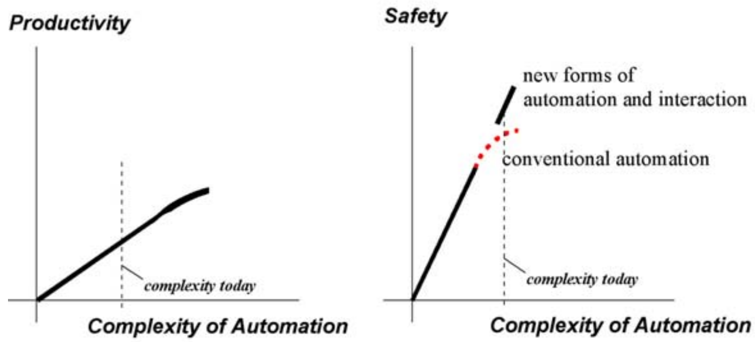


**Figure 5 – Potential Effects of Automation Complexity (Onken, 1999)**

Through intense and recurring training of professional pilots, the commercial aviation was able to maintain a relatively high level of safety (Billings, 1997), but the transfer of this kind of automation to domains with less trained users is not advisable. Moreover, the attempt to improve productivity by increasing complexity with conventional automation might even decrease safety, as Onken (1999) predicted (Figure 5). New forms of automation and interaction have to be found. Is there another, more efficient way to conceptualize an automated vehicle and its operation, perhaps in the form of a metaphor?

## Mental Models, System Images and Metaphors in Design

To describe how a metaphor works, let's take a look into the relationship between the user's mental model and the communication between designers and users, which is limited to what Norman (1990a) calls the ‘system image’:

> *The user's model is the mental model developed through interaction with the system. The system image results from the physical structure that has been built (including documentation, instructions, and labels). The designer expects the user's model to be identical to the design model. But the designer doesn't talk directly with the user -- all communication takes place through the system image. If the system image does not make the design model clear and consistent, then the user will end up with the wrong mental model.*

The designer usually has to expend a great deal of effort in developing and communicating the system image, not only to the user, but also to other people involved in the design and training processes. This communication can be more effective with a ‘seed crystal’ in form of an appropriate metaphor:

A metaphor (Greek, Meta = more highly organized, Phor = bear) transfers meaning from one thing (source) to another thing (target, see e.g. Neale & Carroll (1997)), creating something new (blended target). As with the desktop metaphor for manipulating electronic documents on a computer, the source can be something in every day life or nature applied to the target such as a technical application, concept, task or function. Like with the desktop metaphor, not all aspects of the source are copied to the target; the metaphor has certain plasticity such that it can be, and has to be shaped and adapted. If this plasticity is not overstrained, a user can easily understand and operate the blended target, the design metaphor can be mapped into an initial mental model and refined by using it (Figure 6).

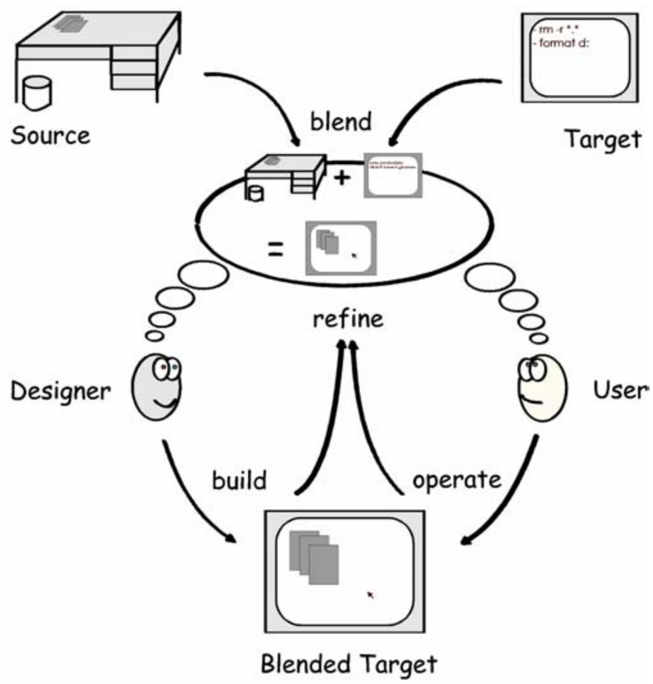


**Figure 6 – How a Design Metaphor Can Work**

## Introduction to the H-Metaphor

What could an appropriate metaphor for automated vehicles be? To avoid falling into purely technical applications too soon, let's leave technology for a moment and stretch our imagination to a situation in everyday life:

Imagine you are riding your bicycle through a wooded park. It's a beautiful day outside, but you are late for an appointment so you're in a hurry. There are crowds of people around enjoying themselves and there are also other cyclists riding nearby you. You're trying to avoid hitting anything and also get to your appointment on time, but you're not very familiar with this park and you need to keep referring to your map. The problem is that even though you're a skilled cyclist, it's very difficult to steer your bike and read a map at the same time with all these trees and people around you, so you are constantly forced to stop. As the time for your appointment draws nearer you keep thinking to yourself — *could there be a better way to steer through an environment with obstacles without having to stop every time you need to do something else?*

Now imagine that you happen to glance up and notice a policeman in the distance moving quickly through the park. He is visible above the crowd, but you can't see what he is riding. You become curious as you watch him because, although he is constantly diverting his attention to other things or people around him, he appears to have no trouble moving among all the obstacles through which you just rode. Finally, the policeman comes into a clearing and you see that he's riding a…

Horse?! If you were riding a horse, you would be able to read your map and be confident that you would not hit any trees or run into people because horses instinctively avoid obstacles. And, using physical feedback through the seat of your pants and your reins, you are constantly aware of what your horse is doing, even while focusing your attention elsewhere. If the horse is unsure about where to go, it may slow down, and seek a new obstacle free path while trying to get the rider back into the loop.

The horse might also be aware of how engaged you are and adjust its behavior. If a dangerous situation suddenly pops up, it will try to react before it is too late. You can let your horse choose its path without being completely out-of-the-loop or you can take it on tight reign to reassert a more direct command.

Now apply this image to a new kind of vehicle. Imagine that you could drive or fly through an environment with obstacles and other vehicles, and would be able to focus on other tasks like navigation, communication, or even enjoying the scenery. You could be confident that your vehicle would not hit anything because it senses and avoids obstacles. Through the physical feedback from your haptic interface, an active joystick for example, you are constantly aware of what your vehicle is doing. If your vehicle senses any danger or is unsure about where to go, it will assume a more cautious and stable configuration, and you can feel where the vehicle is trying to lead you. The vehicle might also be aware of how engaged you are and will adjust its behavior. An extreme example would be if the operator is incapacitated and the vehicle maneuvers to a safe state. If some sudden danger pops up, it will react before it is too late. You can let your vehicle go without being completely out-of-the-loop, or you can reassert a more direct command, for example, by taking a tighter grip on your haptic interface.

Implementing this metaphor may make the act of driving or flying safer and more natural than current automated vehicles. Rather than surrendering ourselves to fully automatic vehicles, we could let the vehicle do what it does best and nevertheless retain authority. However, before we look into more details, some points have to be made clear:

1. The basic horse metaphor is not new; see the Greek mythological flying horse Pegasus. Connell and Viola (1990) used the horse as a motivation for the internal structure of a mobile robot. Zelenka et.al (1996) built a guidance system for a semi-autonomous helicopter, according to informal sources inspired by the H-Metaphor. It's good to have company.
2. Horses are not perfect and require vigilance even during seemingly routine operations. Riding is not as simple as described above and requires substantial training. Pegasus' rider, Bellerophon, was thrown to the ground because he wanted to go too high. We can and have to strive for ease of use and high technical reliability, but even with sophisticated automation, technology will never be perfect and will always require a certain amount of training and vigilance.
3. It would be premature to think that we will be able to build something so wonderful and intelligent as a horse. On the other hand, the horse is the best example of a means of transportation with non-human intelligence that can be understood by almost any culture.

With these caveats in mind, the following sections explore the H-metaphor as applied to user-vehicle interaction, vehicle automation, and multiple vehicle interaction. These sections are intended to provide the reader, in a compromise between width and depth, with some insight into the world of horses, before the application of the metaphor is discussed.

## The H as a metaphor for user-vehicle interaction

Horses are one of a few animals that humans were able to domesticate, and one of even fewer that humans are able to ride on (and survive). A special relationship has developed over the thousands of years that horses have served a variety of roles within society and industry. This development is reproduced in a compressed version each time a young horse is trained or ridden, and each time the human is trained to or rides.

The most obvious part of this relationship is the direct interaction regarding the physical control of the human-horse system. Subtler are the middle term aspects of the relationship like teaching/learning or more long term oriented aspects like social bonding.

What are the details of this interaction, how can we use this for the interaction with intelligent vehicles of the future?

### Physical Control and other short-term relationships

#### *Horse back riding*

A horseback rider controls the forward, backward, sideways and rotational movement of the horse with a combination of continuous and discrete inputs of the hands on the reins (Figure 7), pressure with the legs, seat movement, weight shift, and a limited set of voice commands, e.g. "Whoa" or "Good [boy, girl]" (Figure 8). Appendices I - VII describe this complex interaction in more detail. The horse communicates with the human mainly with body movements via haptic feedback (haptic: = manipulative touch, a combination

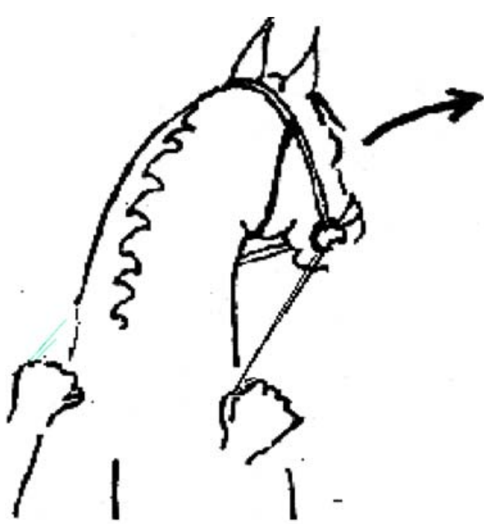

**Figure 7 – Control with Reins (Miller, 1975)**

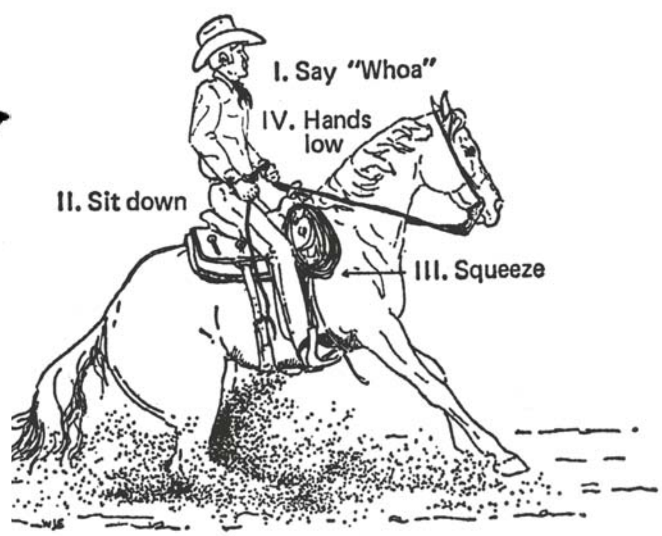


**Figure 8 – Stopping (Western Equestrian) (Miller, 1975)**

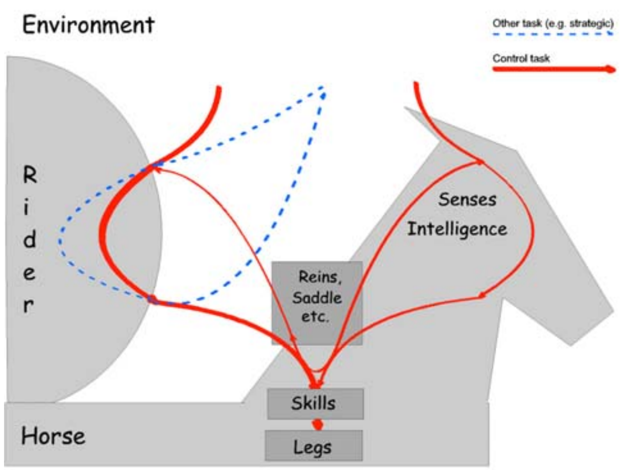


**Figure 9 – Tight Rein Control**

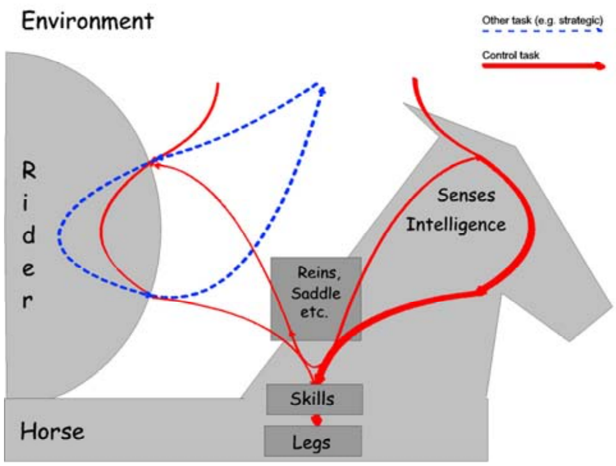


**Figure 10 – Loose Rein Control**

of tactile and kinesthetic, see e.g. Schiff & Foulke (1982). This interaction is assisted with limited auditory cues (e.g. snorting) and visual cues (e.g. orientation of the ears and other body language), see Appendix V.

The rider can, as long as this does not violate certain boundaries, control the horse more directly (Figure 9, "tight rein"), for example in dressage. Or he/she can let the horse have more autonomy while she focuses on something different for a limited amount of time (Figure 10, loose rein): For example, Native Americans riding while shooting a buffalo or cowboys roping cattle. Even in loose rein, the rider stays physically in the loop and can provide additional fine tuning and feedback or can take the horse on tight rein if necessary (Miller, 1975). Tight rein and loose rein may be the extremes of a continuum rather than two exclusive states of operation.

### *Horse cart driving*

Driving a horse cart is another common use of horses (Figure 11). The big difference between driving and riding is that in driving, the contact between the rider's body and the horse is missing. The driver usually sits on the right side of a cart and directs the horse(s) with reins, usually in the left hand or in both hands (Figure 12). Two common auxiliary aids are a long whip, which is applied just behind the pad and on the sides of the horse(s), and simple voice commands. Carts with more than two wheels are usually equipped with a brake, which can be operated with the right hand or a foot and is primarily used by the driver to help the horses cope with the mass of the cart but can also serves as a control and training aid.

As weight shift is no longer applicable, the emphasis is now on the sophisticated handling of the reins. There are several different systems for this. According to the German National Equestrian Federation (GNEF, 2002), all turns are performed by yielding the outside rein with a twist of the hand(s), not pulling the inside one. There should always be a "soft, steady, elastic connection" between the driver's hand and horse's mouth, where "the horse seeks the contact and the driver provides it" (GNEF, 2002). It is important to mention that GNEF (2002) (and most literature directed towards equestrian enthusiasts) describes a quite refined driving system that applies primarily to a small percentage of horse cart users in the world that are interested in sport, competition or show driving. For most people using horses for more utilitarian purposes, it is much simpler: e.g. "Pull right/left, and the horses will turn right/left". For many of these people, achieving a useful level of skill does not involve lengthy, formal training. Rather, informal instruction combined with experience (i.e. trial and error) is sufficient to reach an acceptable level of competence.

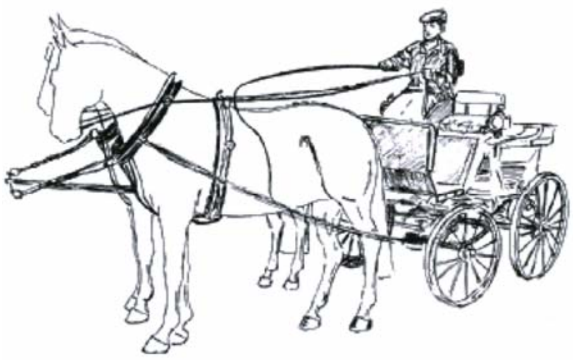

**Figure 11 – Horse Cart (GNEF, 2002)**

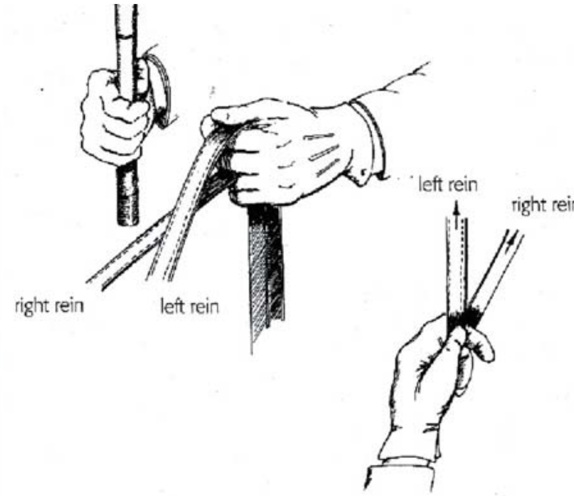


**Figure 12 – Basic Position of Hands & Reins in Horse Cart Driving (GNEF, 2002)**

### *Qualitative concepts of interaction*

The skill of riding and driving horses highlights concepts about the physical interaction, which are more qualitative, but nevertheless interesting. For example, GNEF (2002) describes concepts of rhythm, looseness, impulsion, straightness, contact, collection and permeability; Wanless (1992) formulates a concept of feelage and internal map of feelages. McLean (2003) notes that rhythm is important in the balanced development of the horse and the achievement of suppleness from which other qualitative characteristics of riding/driving evolve (see Appendix VI). Meredith (2003) proposes the concept of the learning tree where each of these qualities: rhythm, relaxation, straightness, balance, impulsion, suppleness and collection build on each other in pursuit of higher level specialized training. More detail about these concepts can be found in Appendix VI.

## Middle and long-term relationships

### *Tension, relaxation and trust*

As in human interactions, the communication of the human/horse system can change over time, dependent on state and personality of both the rider/driver and the animal. Wanless' (1992) "spiral of increasing tension" describes that the horse develops more and more rigidity if handled inconsistently, which might even result in ignoring inputs. As the rider makes more precise and consistent inputs, the horse understands more clearly what is expected and a gradual relaxation of tension develops between them. As the rider gains confidence that inputs will have the desired result, then the horse gains trust in its relationship with the rider.

### *Breaking/Starting under saddle and training*

Horses can usually not be ridden right away, but have to be "broken" or "started under saddle" as young horses and constantly trained together with the rider. The goal of this process is to generate a gentle, reliable, trustworthy, obedient horse that can be ridden by "anyone" (Miller, 1975). The breaking and training of horses relies heavily on learned response to stimuli, reinforced with positive or negative feedback. Successful training activities consider the natural responses of the horse and desensitize it towards unfamiliar stimuli (Freeman, 2003). One part of this process is to teach the proper response to the various cues, which Miller (1975) calls a "language of words and signs". Another part of breaking is "sacking", where the horse is gradually confronted with unusual stimuli (e.g. a sack) and learns to ignore the irrelevant without "spooking".

### *From Social Hierarchy to Bonding*

Horses instinctively function within a social hierarchy where their position and role (e.g. leader or follower) is unambiguously determined and maintained through a variety of actual and symbolic confrontations with other herd members (Budiansky, 1997). A horse naturally assesses a rider's relative position on this hierarchy. This characteristic affords the rider an opportunity to assert their dominance in the relationship or conversely, if demonstrating inexperience or uncertainty, they may be placed lower in the hierarchy with significant consequence as to whose lead will be followed, particularly in high-risk situations. Horses may challenge their role from time to time if they perceive a change in status is needed. Clear and concise actions help the horse to understand this order, to relax and form a stable bond with the individual.

## Implications for the interaction with an automated vehicle

What would a future H-Mode as a mode of strongly haptic interaction between a human and an intelligent vehicle, based on or inspired by the H-Metaphor, look and feel like?

Horses were not intentionally designed to be ridden or driven; some aspects are more cryptic or counter-intuitive than need be for technical implementation. Other aspects like the "breaking" process should initially be taken more as a guideline for the stepwise development and test than for the operation of such a vehicle.

A starting point for an H-Mode could be a side stick with active force feedback, which would more resemble the situation in horse cart driving, and expand from there into

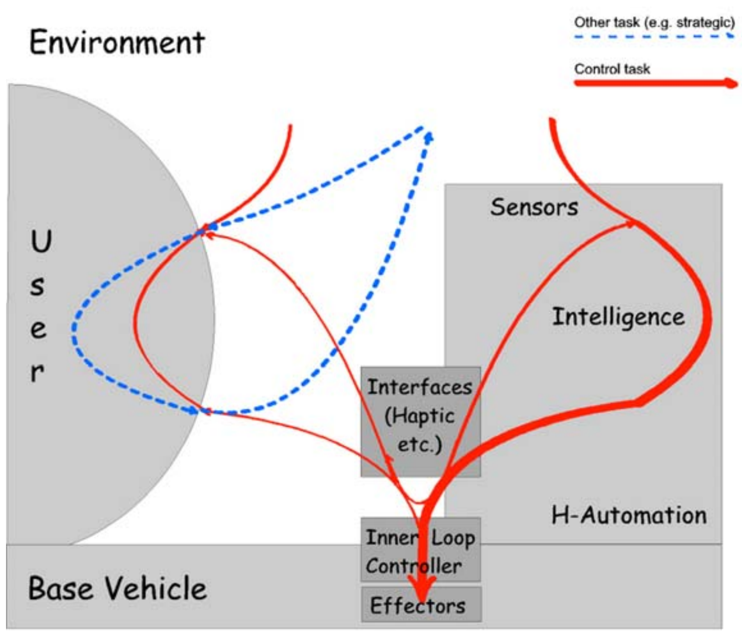


**Figure 13 – Loose Rein Control in H-mode**

more multimodal, complex interaction.

On the other hand, the metaphor has a certain plasticity and therefore opens up a much larger design space. Even if this plasticity is limited, it is, at this point of the discussion, a fragile balance between narrowing down the design space too much and leaving it too open. Appendix VIII describes therefore only generic characteristics of a future H-Mode, compared to conventional and conventionally automated vehicles. Touchstones here are: bi-directionality, a mix of discrete and analog communication, and a multimodal interface with a strong haptic component allowing both human and machine to be in the physical (i.e. sensory-motor activity) loop simultaneously. Figures 13 and 14 show a generic information flow diagram for a future H-Mode.

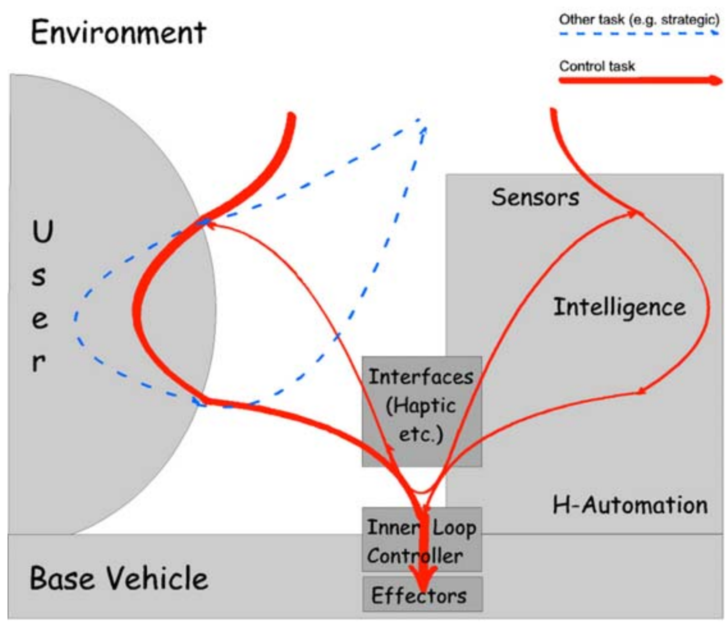


**Figure 14 – Tight Rein Control in H-mode**

At this point of the discussion, Tight Rein and Loose Rein can represent explicit modes inherent in the technical solution, and/or implicit modes that shape out in the use of such a technology. At the time of this publication (2003), many connecting points exist between Tight Rein and ongoing work on haptic/tactile assistant or cueing systems for cars, aircraft or helicopter, as described in e.g. Gerdes & Rossetter (2001); Jeram (2002); Mücke (1999); Penka (2001); Tichy (1995) and many others. For a future H-Mode, it is open whether Tight Reins and Loose Reins are more crisp modes or the extremes of a mode continuum, and what characteristics the transitions will have, for example whether there will be a mode where both human and machine contribute equally or whether this is prevented or made more difficult with a "teeter-totter" characteristic.

A person could, for example, initiate the transition of "lead" from the H-vehicle to herself, i.e. from loose reign to tight reign, by applying a "firm grip" (upper arrow, Figure 15). Other transitions might be initiated by discrete signals in combination with decreased or increased force, or a lead into a specific maneuver.

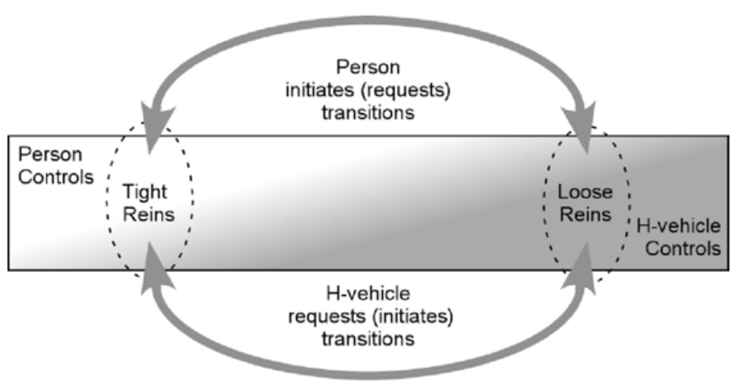


**Figure 15 – Potential Transitions in a Future H-mode**

Another application of the metaphor could lie in the middle term and long term mechanisms: While with a specific conventional and conventionally automated vehicle only the operator adapts over time, horses have the ability to adapt to the rider and to the environment, learn over time and to form a bond with an operator for a long time. It might be necessary for initial implementations of an H-Mode to concentrate on the short-term relationship, i.e. direct physical interaction, first. Based on that, middle and longer-term relationship and adaptability can be a challenging future direction.

The biggest difference between this concept and conventional automation however has to be in an inherent quality that allows the user to understand how to interact with this intelligent vehicle, which Svanæs (1997) calls "Interaction Gestalt" in relation to the Gestalt concept of psychology (Koffka, 1935). An interaction Gestalt beyond words can be experienced by actually riding or driving real horses. A similar Gestalt is mandatory in the interaction with an H-Mode equipped vehicle.

The degree of freedom in the design of this Gestalt, the transitions and other aspects of this interaction is relatively high, but could in the long run lead to a standardized set, a commonly spoken and understood "language" for this kind of interaction between humans and intelligent vehicles. This language should be similar for different classes of H-inspired vehicles, e.g. air vs. ground, because it might be the same individual who drives these vehicles in succession. Beyond the technical implementation of an H-Mode, the H-Metaphor can be a rich source of inspiration for many other aspects of human-vehicle interaction.

## The H as a metaphor for highly automated vehicles

Horses are incredibly capable and complex entities, and like other animals, have been shaped through hundreds of millions of years of evolution to survive in their specific, dynamic and potentially dangerous environment. What are their physiological and behavioral characteristics that allow these capabilities? What aspects, if any, can be transferred to automated vehicles?

### Physiology

The anatomy and physiology of most animals and certainly mammals such as the horse is amazingly sophisticated. The internal anatomy of horses is commonly divided into digestive, circulatory, respiratory, immune, urinary, endocrine, nervous, skeletal, muscular, and reproductive systems. While the top-level functions of these organ systems are familiar to most, at microscopic scales, the

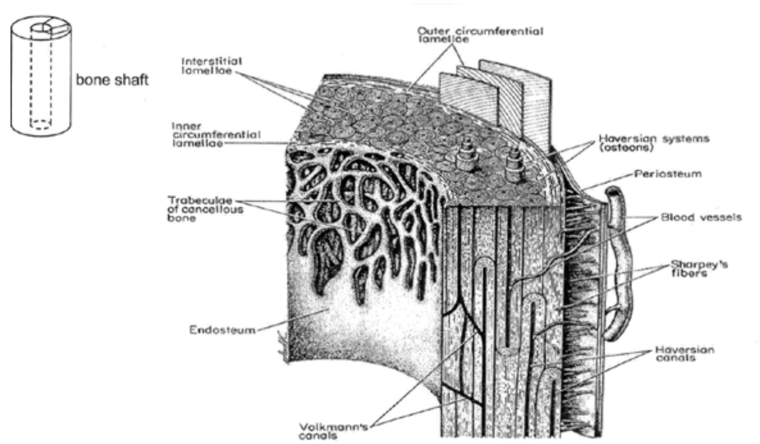


**Figure 16 – Detail of Bone Tissue (Martin, et al, 1998)**

intricacy and interactions of these systems is astonishing. Consider that the bones of the skeletal system, which initially appear to be simple structural members, are composed of living tissue (see Figure 16), capable of repairing damage and adaptively restructuring to prevent future damage (Garita & Rapoff, 2003). The intent of this example is not to presume that a similar level of microscopic integration is required for successful h-inspired vehicles, but rather to heighten awareness of the pervasive presence of distributed, active processes throughout natural systems in order to achieve adaptability and fault tolerance, even in seemingly simple and static elements.

Perhaps of most relevance to the H-metaphor is the nervous system including the brain. Horse brains are composed of tens of billions of neurons, many having tens of thousands of interconnections (Koch & Laurent, 1999). The brain, combined with the other elements of the central, peripheral, and autonomic sub-systems of the nervous system, extract, process, and act upon information from the external (e.g. sight, sound, touch, smell, temperature) and internal (e.g. pain, propreoception, chemical changes, osmolarity) environments. Similarly, the nervous system has massively distributed means of controlling the body's muscular (i.e. actuation) system. These capabilities facilitate a broad range of automatic control and maintenance processes that preserve nominal system performance over a wide range of conditions and failures and without conscious effort. This distributed architecture also grants a high degree of fault tolerance and robustness despite limited accuracy and reliability of individual components.

## Relationship between physiology and behavior

It is important to recognize that the physical capabilities and behaviors of the horse co-evolved as an integrated system adapted to life in a particular ecosystem. The close coupling of these characteristics is illustrated when considering the horses' flight-based predation defense. The horizontal field of view afforded by the eyes (the largest of any land mammal) and supporting head structure approaches 360 degrees (see Figure 17) and is well suited to the detection of distant predators. The muzzle creates a long separation between the mouth and eyes and allows grazing while watching for danger. However, it also creates a blind spot in the vertical field of view as shown in Figure 18. This blind spot prevents a running horse from seeing obstacles directly in front of its feet and is, in part, alleviated by reliance on projections from mental images obtained several strides earlier

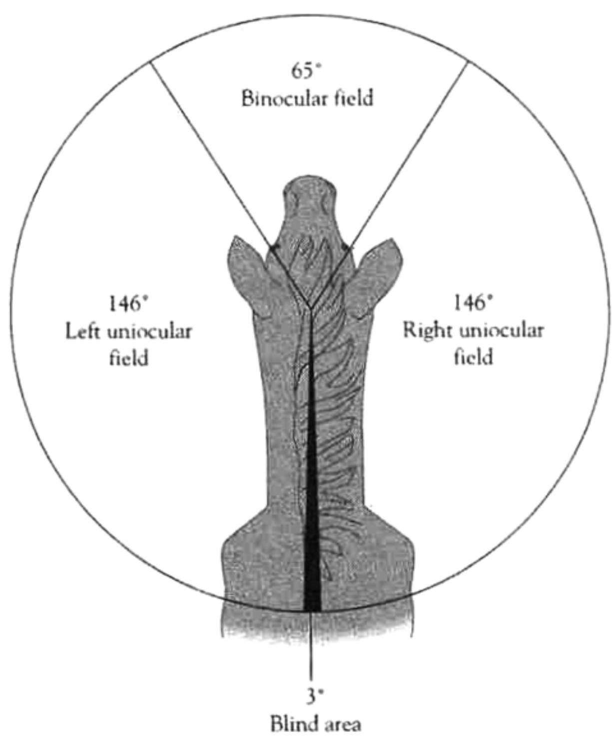


**Figure 17 – Horizontal Field of View (Budiansky, 1997)**

(just as humans tend not to stare at their feet while walking). The construction of these spatially accurate mental representations is aided by a 65-degree region of binocular vision as well as an ability to perceive monocular depth cues such as perspective as evidenced by susceptibility to the Ponzo illusion (Budiansky, 1997).

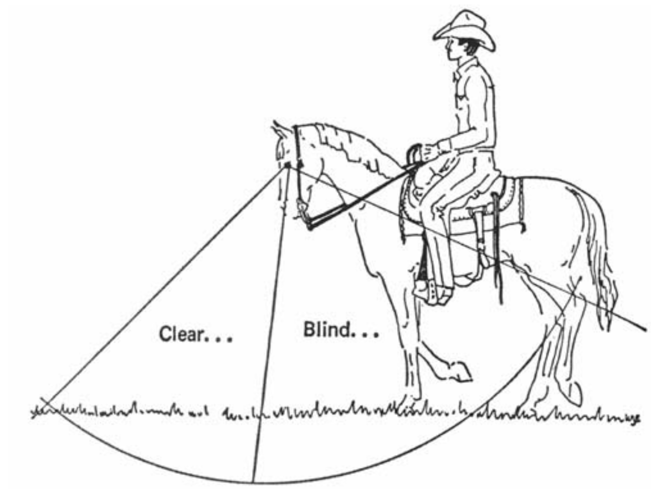


**Figure 18 – Vertical Field of View (Miller, 1975)**

Like other mammals, the brains of horses are anatomically and functionally divided into three major regions, the hindbrain, midbrain, and forebrain as shown in Figure 19 along with major sub-regions and neuro-information pathways. In very general terms, the forebrain performs higher-level, cognitive processing and integration; the hindbrain (e.g. medulla and cerebellum) performs lower-level, involuntary functions and hard-wired signal processing and control; and the midbrain serves certain intermediary functions. Compared to mammals of similar size, horses' brains are actually above average in terms of overall size (i.e. mass). Consistent with their flight response and need to coordinate four large limbs while running over rough terrain, a disproportionate brain mass fraction is dedicated to functions associated with sensory processing and locomotion such as those performed in the cerebellum. The cerebellum of the horse is roughly nine times larger than that of a human.

Defining horses' higher-level cognition and predictive intelligence is considerably more problematic than the basically reactive behaviors involved in predator detection and locomotion. Horses and other ungulates (hoofed animals) are rarely the subjects of laboratory tests of cognitive ability. Bundiansky (1997) summarizes the results of maze and pattern recognition studies in which horses demonstrated a modest ability to learn associations, and an excellent ability to recall these associations months later. Byers (2001) details ethological observations of pronghorn antelopes which strongly suggest these animals, which are genetic cousins of horses, can deliberatively plan their actions in complex, dynamic situations important to survival or reproduction. It seems appropriate that concepts originally described for human cognition can partially be used for some non-human animals like horses as well. An example is Rasmussen's skill-rule-knowledge based schema (Rasmussen, 1983), where at least the skill based and the

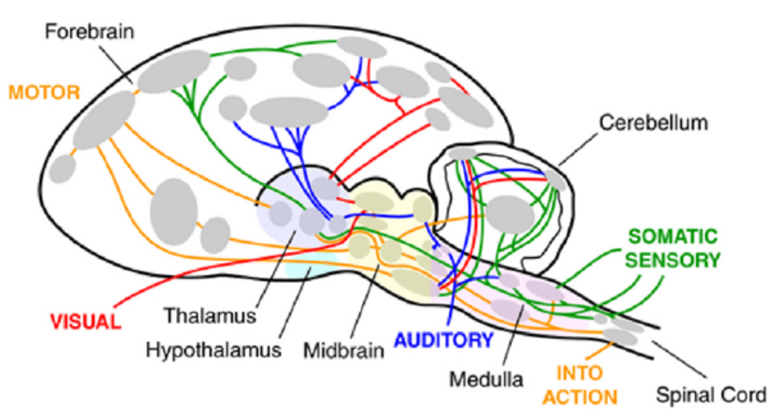


**Figure 19 – Diagram of Horse Brain (Dizack, 2003)**

rule based level of behavior can be applied. Another example is Endsley's (1995) concept of situation awareness, which describes "*the perception of the elements in the environment..., the comprehension of their meaning..., and the projection of their status in the near future*", based on mental models in form of schemes and scripts.

While animal behavior is largely instinctive and shaped by evolution, it demonstrates that such specialized intelligence performs adequately in many complex, real-world situations. Despite clear limitations, it has been relied on even with human life and safety at stake, such as riding a horse over hazardous terrain.

## Implications for the design of automated vehicles

Like any metaphor, the intent is not to copy the form or function of the inspiration verbatim. Rather, the goal is to gain insights from its salient features that benefit the target application. As applied to the vehicle as an independent agent, the essence of the H-metaphor is a vehicle that can autonomously operate safely and purposively in its intended environment. In the absence of user direction, such a vehicle should seek a condition of safety such as stopping or staying out of harms way.

From a user's perspective, vehicle behavior should support an integrated understanding not only in terms of required interaction, described earlier as interaction Gestalt, but also of the underlying behavioral capacity and motivation of such a vehicle. This might be understood as automation Gestalt. Furthermore, unlike traditional automatic control systems such as an aircraft flight management system, the vehicle must be able to perform tasks with an ability to account for dynamic environmental hazards and uncertainties.

To achieve these capabilities, the vehicle must obtain and integrate perceptions of the relevant situation elements, including its internal fitness and the intentions and involvement of the user, into a meaningful whole. The vehicle must then formulate and act on a course of action (e.g. a preferred trajectory) that balances potential threats to its well-being, and presumably the well-being of any occupants, with other objectives such as satisfying the desires of the user. To be of benefit to the user, this course of action should faithfully support the user's desires unless there is good cause for deviation. Furthermore, in situations were there is good cause, its important that the vehicle have the transparency of will to ensure that the user intuitively perceives both the gravity of the situation and the vehicle's proposed resolution. To be practical, an H-vehicle must have predictable, situation-appropriate and comprehensive behaviors that allow the operator to reliably divert attention elsewhere if necessary, particularly during otherwise high-workload situations. These situations imply an ability to work competently even at the boundaries of the vehicle's performance envelope and during non-routine situations, which with late 20$^{th}$ century automation is ineffective or even dangerous (AvWeek, 1995; NTSB, 1996). At the time up this publication (2003), such approaches can be partially found in cognitive system architectures, e.g. in autonomous cars (Dickmanns 2002) and uninhabited air vehicles (Putzer et.al. 2001). Other promising elements might be found in behavior-based robotics (e.g. Arkin, 1998)

The success of animals like horses despite relatively limited "general" intelligence suggests focusing on a limited range of situations and behaviors critical to the immediate safety and intended use of an intelligent vehicle rather than pursuing abstract, human-like intelligence.

The challenge of achieving animal-like behavior in an artificial vehicle should not be underestimated. Simple, H-inspired systems providing performance superior to conventional automation and enabling the user to have a more consistent mental model of the automation are probably within the reach of early 21st-century technology. Comprehensive, horse-like machine intelligence is likely to be a further-term, but reachable objective.

## The H as a metaphor for multiple vehicle interaction

### Group and Social Behavior

Horses have a complex behavior towards things, especially towards other horses, as described by a paired-ethogram (i.e. catalog of a species' pair interaction behaviors) (McDonnell, 2003). Horse survival in the wild depends on two basic instincts that dominate their group behavior (W3COMMERCE, 2001): To gain safety in numbers, and an ability to run quickly from trouble.

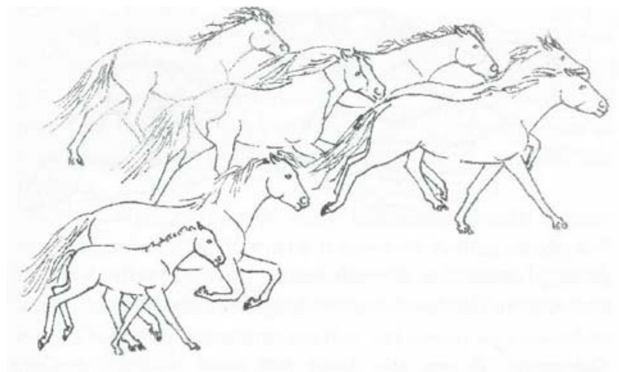

**Figure 20 – Group Behavior in Horses (McDonnell, 2003)**

The instinct for safety in numbers manifests itself in a tendency for one horse to follow another (Figure 20). This is particularly true when the alpha horse, which has a strong affinity for leading others, is involved. In return, a competent alpha horse, as heard leader, is watchful and looks out for the safety of everyone (McGreevy, 1996).

Horses also have developed a natural instinct to avoid being separated from the rest of the herd, as they have experienced safety in numbers. A behavioral expression of this is chasing, where one horse tries to catch up to and take over another in a playful way. A more extreme illustration, one that also demonstrates their ability to run from trouble, is a stampede, or the running of a group together as a unit at high speed.

Over time, people who work with horses have found ways to modify these basic instincts and use them advantageously. Miller (1975) suggests that horses' ability to herd cattle or chase buffalo is a modification of their instinctive behavior.

Horses' social behavior is observable. They desire companionship, and naturally bond with a human partner. They prefer to be in the company of other horses, often exhibiting "barn-sourness" if removed from the herd in the barn (Miller, 1975). When there are multiple riders on multiple horses, they have learned that for best results they should all start moving simultaneously. There is also a pecking order between horses beyond the dominant alpha. Trainers have learned to make the most of this trait by using an older horse to lead a young one in training.

## Implications for the interaction between automated vehicles

How do these attributes translate to vehicle automation? Traditionally, we have treated vehicles independently, but the introduction of intelligent vehicles calls for consideration of group dynamics. We do not necessarily have to copy features like flight instinct or alpha horses, nevertheless the metaphor opens possibilities for exploitation. For example, the ability to follow could be transferred to the vehicle domain for operations such as final approach spacing into a busy airport, or diving in close distance on a highway (platooning; see Stotsky, Chien, & Ioannou (1995)). These concepts could be applied to a wide spectrum of control approaches across various transportation domains; from highly centralized air traffic control to highly decentralized foot traffic.

The introduction of vehicles based on the H-metaphor may afford transformation of transportation technologies to substantially more efficient and safer group operations and provide a mechanism for distributed control between a central agent and individual vehicles. These benefits could be realized through more simple, localized treatment of complex systems. The complex systemic behavior could be controlled by self-organization amongst intelligent vehicles at a limited level. As an example of this emergent simplicity phenomenon, in the future we may decide to travel inter-city by platoon, “swarm” or “herd”. The vehicle’s control system would take care of the details of merging into traffic, maintaining relative spacing between vehicles to close tolerances, and departing from the traffic flow. The travel task, though in toto more complex, would become simpler for the operator.

With application of shared control between vehicle and operator, however, caution is necessary. Regulation reliant on distributed control can exhibit emergent, or seemingly unrecognizable, complex characteristics (Bar-Yam, 1997). Yielding inter-group dynamic control to the vehicle’s systems has to be done judiciously. The operator must retain appropriate authority over the situation, and rules of engagement must be established and honored. We do not want a destructive stampede.

## Risks and Chances of applying the H-metaphor

Good design is not free of form. This paper described, with the help of a metaphor, one potential form for automated vehicles and their interaction with the user and with the environment. The paper is **not** proposing:

- A replicate of a horse
- A temperamental vehicle, like some horses
- A vehicle intended to routinely function without a human operator (exceptions might be abnormal conditions like operator incapacitation).

What the paper is proposing is a vehicle:

- That supports the human operator in a "horse-role" like a good, well trained horse
- That has a multimodal interface with a continuous haptic component that enables communication beyond simple proportional relationships
- That has a horse-like autonomy and transportation skills and interacts appropriately with its intended environment, including other vehicles.

Depending on intended use and technological maturity, it may:

- Be trainable
- Develop a relationship with the operator (e.g. tailor expectations and behavior based on individual operator interactions over time)
- Be combined with other technological tools (e.g. intelligent planning devices or assistants)

Good design often begins with inspiration, but inspiration alone does not necessarily lead to good design. Significant technological and scientific skills and perseverance is needed to turn inspiration into reality. A vehicle modeled on the H-metaphor must exceed a minimum threshold of capability, intelligence and reliability; otherwise it could go lame or might buck. Late 20$^{th}$ century technology is sufficient to develop and test initial implementations, especially for well-structured domains or lower task complexity. For more complex domains, further advancement of enabling, constituent technologies will be necessary. The following is a partial list of these technologies:

- Highly distributed sensing and actuation
- Information fusion and perception
- Robust behavior generation with uncertain and incomplete information
- Software and hardware reliability, verification, and validation
- Intent inferencing through context and simple but flexible interaction
- Concepts of active, bi-directional haptic interfaces beyond simple sticks and 20$^{th}$ century's virtual reality

Portions of this effort are non-technological: Successful implementation requires multidisciplinary understanding and cooperation. On the one hand, the plasticity of the metaphor can bridge disciplines and create a balance between different people and aspects of the design and operation of automated vehicles. On the other hand, the portion of the community more focused on quantitative methods and "hard" technology might need time to accept or at least tolerate some of the "softer" concepts described here. The secondary meaning of the "H", haptic, might serve as an intermediate stepping-stone towards the primary meaning.

The expectation is that the H-metaphor can cast technological complexity into simplicity for the user. However, the lessons of unintended consequences learned from conventional automation have to be taken seriously. Human factors engineering and analysis must accompany development from the very beginning. The entire process will likely require multiple iterations before good systems are realized. A potential transition path from 20$^{th}$ century’s automation to full H-inspired systems might lead via multimodal cueing systems with a significant haptic component.

By taking up this challenge, we not only have the chance to sharpen our technological and scientific skills, but to produce technology significantly better than what we have. As an emerging concept, there are both risks and opportunities. Feedback of the scientific and technical community is vital and strongly encouraged.

What do you think?

## Appendixes

While implementations of the H-metaphor should be intuitive and simple to operate, the source of the H-metaphor, riding, is more complex than described so far. Moreover, the details of riding could provide additional inspiration for human machine interaction beyond simple sidesticks.

Riding well requires an understanding of the mechanics of the horse's movement, communicating and working with the intelligence of the horse, and knowing the techniques for the human to achieve the desired behavior. Riding can be refined as demonstrated in competitive jumping, English or western equitation or cart driving and requires training to meet the standards of the sport. Riding can be rudimentary – climbing in the saddle and hoping that the horse responds the way the rider intends. For people who grow up with horses or adapt to horses over a long time, riding can also be quite naturalistic – just riding without having to think about it consciously.

Appendices I – VII address some of the general methods used for riding, while Appendix VIII compares horses/future H-inspired systems with conventionally automated systems.

## Appendix I: Controlling the Speed of the horse

The main cue for a horse to start moving or increase speed is a squeeze with both lower legs, sometimes assisted with a verbal cue and/or an external incentive such as a light tap of a whip. Speed is structured in discrete gaits (walk, trot, canter, gallop) and transitions between these gaits. The following highlights the methods to transition from a slow to progressively faster gait:

- Stop → Walk: Light squeeze with both calves simultaneously. Maintenance of the walk is through alternate light pressure from the calves
- Walk → Trot: A quick double squeeze of calves in rhythm. Whether posting or sitting the trot, maintenance of the gait is through simultaneous inputs with the calf of the legs
- Trot → Canter: Place the outside leg back, inside leg just behind the girth, kick simultaneously, and maintain light rhythmic pressure like a march with outside leg
- Canter → Gallop: Kick with both legs, upon reaching gait, rider changes to "two point" position, slightly standing with legs against the horse, torso over center of gravity, and slightly leaning forward with the motion of the horse

The main cue for a horse to move slower or stop is a discrete pull and release of the rein, together with a shift of body weight slightly backwards and down into the seat of the saddle and squeeze of each calf, sometimes accompanied by verbal cues like "Whoa". Downward transitions, i.e. canter to trot, trot to walk can be accomplished with a "half halt" to rebalance the horse prior to asking him to decelerate.

Backing a horse should be considered an aspect of impulsion that is being channeled in the opposite direction. Hold a short, steady rein and apply leg pressure to prevent the horse from taking a single step forward. The horse will take backward steps. The rider will relax leg pressure as a reward and can continue to backup using only slight leg and rein pressure.

## Appendix II: Turning

The following is an example for the subtle fine tuning (tight rein) during a turn: Turning the horse left or right requires rein input and leg pressure on the inside of the turn. To turn a horse left, “squeeze” the left rein, maintain steady pressure of the left calf and make light inputs with the right calf to continue forward movement. The continuous leg on the inside of the turn keeps the horse’s midsection and shoulder from “falling” into the turn, while the calf inputs on the opposite side keep the haunches and right shoulder from falling away from the turn path (Figure 21 a). This provides a coordinated turn (Figure 21 b) much the same as using both stick and rudder on the aircraft keeps the tail from skidding out of the turn. In western equitation, the reins are looser and the cue is to pull the reins together over to the left so that the right rein is against the horse’s neck. Leg inputs are the same.

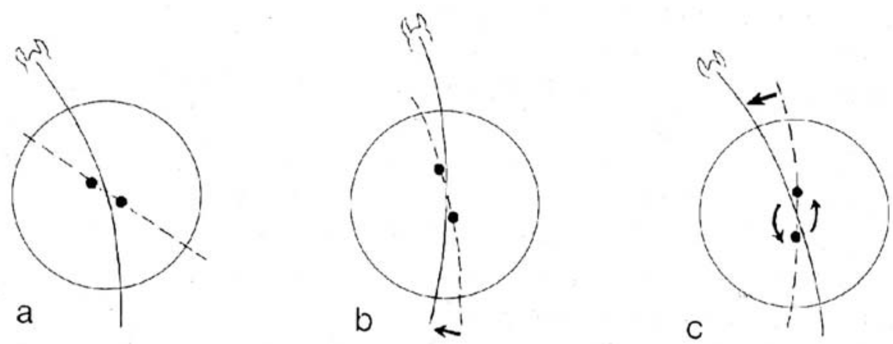


**Figure 21 – Leg Pressure in Turns or Rotational Movement (Wanless, 1992)**

Unlike most vehicles, horses can be rotated left or right on the spot. The main cue for this rotation is asymmetric pressure from the right and left calf of the rider's leg, as if the rider would physically turn the horse between his/her legs. The main principle for the horse is to avoid the pressure. The rotational input plays an important role in every lateral movement (see above, left/right). As an example for the complex coupling of rotation and lateral translations, Wanless describes how rider and horse move towards a circular fence and turn left to ride the circle in counter clockwise direction:

> *"On circle left, the rider's seat bones lie on the ten to four axis, as in (a). To position the horse into traverse on the circle, they shift around to five to five, holding the horse's spine more closely between, as in (b). To position him into shoulder-in on the circle, they almost reverse their placings, coming to five past seven, and again, it is as if they hold the horse's spine more firmly between them, as in (c)."* (Wanless, 1992)

Riding the circle "right" is a mirror image of the above described movements.

## Appendix III: Weight Shift

While a beginner might initially focus on the obvious cues like rein and leg input, the focus of more sophisticated riding shifts to more subtle (and difficult) cues like weight shift (Figure 22). As Wanless (1992) points out, "the secret of good riding lies in gaining control of the center of gravity of the combined rider/horse system, for only this makes the horse malleable...". For the rotational movement she describes

"If the horse falls onto his outside shoulder, …, she[the rider] is placing her center of gravity directly over his, so that she gains control of the center of gravity of the combined rider/horse system. She …aligns her 'plugs' with the 'receptors' at the end points of the horse's trapezius muscles. Then, …, movement of her seat bones causes the equivalent movement in the horse's 'receptors', and they remain united in a way which makes them move as one." (Wanless, 1992)

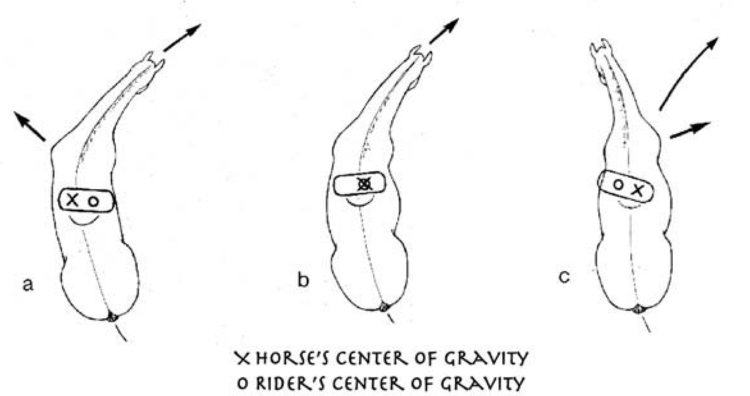


**Figure 22 – Weight Shift in Riding (Wanless, 1992)**

For a description of the influence of weight shift on the forward movement, see Mary Wanless' book, *Ride with your mind* (1992).

## Appendix IV: Up/Down and Jumping

Unlike birds or the mythical horse Pegasus, horses are, not optimized to move in a three dimensional environment. The exception is jumping over obstacles, which is more a trained than a natural activity (Moore, 2003). Jumping is trained and executed using cues at various distances from the rails. A horse jumps an obstacle because the rider provides cues as to direction, speed, balance, impulsion (heighten/distance of jump) and takeoff point. The rider's lower legs press firmly onto the horses sides just behind the girth and the heels sink down into the stirrups as if looking forward. The horses gait should be balanced, rhythmical and forward. On the approach to the jump, the rider determines the correct spot from which the horse will be cued for takeoff over the obstacle. The jump may be approached with the rider in a 2-point position or seated until just before the takeoff point. At the takeoff point, the rider must be centered over the center of gravity (CG) of the horse. The rider bends forward from the hip joints enough to place the center over the feet but never ahead. The rider s seat is out of but remains close to the saddle. Looking straight ahead and not at the jump, the rider s hands slide up onto the horse's crest (top line) 2-3 inches putting slack in the reins. The rider holds a little body weight on the horses crest for stability until it bascules or arcs over the obstacle. This gives the horse full freedom of his head and neck. The rider then sits or becomes more upright and brings his hands back towards the withers with the first stride on the ground to reestablish control. The horse will jump most successfully if all the cues are appropriate and timely. (Swift & McFarland, 1985; Wanless, 1992).

## Appendix V: Multimodal cues in the human-horse communication

Horses rely on multiple senses to communicate and detect the state of their environment. They communicate to humans and with other horses through oral signals and posture as described in Miller (1975).

Auditory Signals:

- Snort = warning sound
- Neigh or whinny = distress call
- Nicker = greeting
- Squeal = anger
- Stallion or mating call
- Rolling sigh (soft) = pleasure, comfort

Ears as visual signal:

- Anger (turned back and laid down)
- Interest (ears pointed forward, but body relaxed)
- Fear (ears pointed forward, body tense)
- Relaxation (ears at angle to the side)
- Listening to rider (one ear forward, one ear back)

Tail as visual signal:

- Kink (ready to run and play)
- Held high (play)
- Waiving (comfortable)
- Between legs (frightened)
- Switching (irritated)

Verbal commands to a horse are based on training, however, basic commands or feedback such as Whoa, No, Good [boy, girl], walk on, and a rolling whistle are generally used. Generally, high-pitched short, sharp sounds have the effect of making the horses go forward, while low-pitched, short, drawn-out sounds have a calming and therefore slowing effect (GNEF, 2002)

## Appendix VI: Qualitative concepts of H-interaction

- *Rhythm*: Refers to the regularity of the steps or strides or beat in each of the speed gates. Interesting for the interaction is that "no exercise or movement can be considered good if it contains rhythm faults, i.e. if the rhythm is lost". While GNEF (2002) mainly talks about the rhythm of the horse, it seems to be interesting to apply this term to interaction and users as well, as it was done in for pilots (Wioland & Amalberti, 1996).
- *Looseness*: German "Losgelassenheit", a state of relaxation, both mentally and physically, where the "movement cannot be considered correct unless…without tension". While GNEF (2002) is mainly focused on the horse, it might make sense to transfer the concept to the whole interaction in the user-vehicle system.
- *Contact*: The quality of the "soft, steady, elastic connection between the driver's/rider’s hand and the horse's mouth. The horse should … 'seek' a contact with the drivers hand" (GNEF, 2002).
- *Impulsion*: A quality of the movement of the horse: "A horse is said to have impulsion when the energy created by the hind legs is being transmitted …into every aspect of the forward movement" (GNEF, 2002).

- *Straightness*: "A horse is said to be straight when … [it's] longitudinal axis is in line with the straight or curved track which it is following (…covering the track)". (GNEF, 2002)
- *Collection*: In collection, the horse shifts his center of gravity more over his hind feet by increasing the bend in his hocks and stifles, achieving a balanced state of energy. The topline will appear stretched and rounded while the frame is shortened because the hind feet are closer to the center of gravity. That lowers his hindquarters, shortens his strides. In true collection, the horse should not loose rhythm but will have a shorter, more elevated stride than during a "working gait" (Hill, 2002; Meredith, 2003).
- "*Through/Permeability/Letting the aids through*": The horse is prepared to accept the rider's aids obediently and without being blocked by tension at any point.
- *Feelage/Internal map of feelages*: A holistic, non symbolic memory representation of one or several senses combined: "The…mind has a filing system which stores visual information as images, and kinesthetic…information as 'feelages'; so, without recourse to language, it can flip through files in any situation, and find out if the face, or the feel, matches up to anything it has previously experienced.". 'Internal map of feelage' seems to be an understanding or mental connection between the feelages, especially about the required action to get from one feelage to another. Wanless (1992) also points out that some people can talk very eloquently about riding (left brain knowledge), but do not have a rich store of feelages (right brain knowledge) which enables them to practice what they preach.

With respect to the science of human-machine interaction and control, some or all of these concepts might be outside of the limits of some chosen scientific paradigm at the time of this publication (2003). They might at least give valuable qualitative hints for the development of a H-metaphor based system. Especially the concept of feelage, where there is a gestalt incorporating anticipation, sensation and response, is worthy of consideration as interaction with the haptic system advances. All the above-mentioned concepts carry with them an inspiration that should be used for the future development of the art and science of human-machine interaction towards a more constructive balance between left- and right brain related aspects.

## Appendix VII: A brief summary of training

A horse's behavior is initially based on instinct but through training relies heavily on learned response to stimuli that are reinforced with positive or negative feedback. Shaping behavior through training that considers horse logic will give it confidence in its ability to meet task requirements. It is the positive interaction between the trainer/rider and appropriate motivators that facilitate the learning process (McLean, 2003). Punishment or negative feedback is considered to be a poor method of training as it instills fear in the animal towards avoiding a behavior rather than a willingness to perform correctly. In these conditions, the horse learns to trust that nothing bad is going to happen when he's around the rider.

If we subscribe to the theory that practice makes automatic, as was formulated for humans e.g. by Wickens & Hollands (1999), then horses follow a similar principal of learning through study and rehearsal, practice and performing. The horse must, like humans, learn the correct mental model of the task or confusion and unwanted errors will occur (see Carroll and Carrithers in Wickens & Hollands (1999) p 275). Repetition of actions reinforces learning and facilitates the development of appropriate behaviors. Therefore, it is important to consistently apply and release and reapply those pressures to shape and direct every stride the horse takes. Each task should be no more than one step away from something he already knows. The horse learns to trust that nothing bad is going to happen when he's around you. That trust leads to relaxation. And relaxation and rhythm are the foundations for anything you're going to teach a horse.

McNamee-Suter (2003) suggests that pressure (leg, hand, or calf) is the best motivator because of its consistency. Applying pressure is always followed by a release of the pressure upon execution and does not produce fear or pain. Pain used in training is generally in the form of slight discomfort such as kicks with the heel, spurs and/or whips. It may be nothing more than the horse moving away from the unpleasant stimulus and moving in an appropriate way only to remove the discomfort. As a disciplinary technique it must be applied immediately after disobedience. Secondary effects can result such as the sight of a whip that may facilitate the horse attending partly to the rider's cue with an eye on the stinging end of the stick, which is one of the reasons why carthorses usually have blinders. Spurs associated with leg pressure might be removed leaving the leg inputs as the motivator.

Positive motivators include food, or voice. Voice or praise is given in the form of soft, kind words, petting, and touch, and must be used in conjunction with another means of motivation to achieve positive results. Miller (1975) considers the most beneficial means of rewarding a horse for a good job is to end a training session on a positive note – stopping or changing the task after the horse does a good job. The horse learns to associate proper execution with rest or change.

## Appendix VIII: Generic characteristics of the interaction with conventional vehicles, conventionally automated vehicles, horses and a future H-Mode

| | Vehicle class | | |
|---|---|---|---|
| **Characteristics of the interaction** | **Conventional vehicle** (w/o control automation, e.g. $20^{th}$ century car without cruise control) | **Conventionally automated vehicle** (e.g. $20^{th}$ century commercial aircraft) | **Horse / H-inspired vehicle** |
| **Direction** | Mainly unidirectional | Mainly unidirectional, some bi-directional | Mainly bi-directional |
| **Coding** | Analog / spatial | Mostly linguistic /abstract Some analog / spatial | Mostly analog /spatial, Some linguistic /abstract |
| **Modality** | Multimodal with haptic component | Strong visual component, some multimodal aspects | Multimodal with strong haptic component |
| **Discrete or continuous?** | Mostly continuous input | More discrete input and output | Mix of continuous and discrete input / output |
| **Importance of visual modality for the guidance task** | High | High | Medium |
| **Redundancy in the interaction** | Low | Medium | High |
| **Negotiation of different wills** | None | Non-overt, brittle, "either / or" (automation will is more implicit) | Transparent, fluid ("automation" will is explicit) |
| **Who is in the physical loop, human and automation?** | Human (automation only in low level functions, e.g. a governor in a car) | Exclusive either/or for specific axes | "Automation" and human are in the loop simultaneously |

It is important to keep in mind here, that lists like this, which break down into sub aspects, can only give some general hints. Their ability to describe more integrated, Gestalt like qualities, is epistemologically limited. One way to increase an understanding of potential differences beyond words is to actually ride a motorcycle, drive a ($20^{th}$ century) car with cruise control…and ride a horse.

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Good design is not free of form. It does not necessarily happen through a mere sampling of technologies packaged together, through pure analysis, or just by following procedures. Good design begins with inspiration and a vision, a mental image of the end product, which can sometimes be described with a design metaphor. A successful example from the 20th century is the desktop metaphor, which took a real desktop as an orientation for the manipulation of electronic documents on a computer. Initially defined by Xerox, then refined by Apple and others, it could be found on almost every computer by the turn of the 20th century. This paper sketches a specific metaphor for the emerging field of highly automated vehicles, their interactions with human users and with other vehicles. In the introduction, general questions on vehicle automation are raised and related to the physical control of conventional vehicles and to the automation of some late 20th century vehicles. After some words on design metaphors, the H-Metaphor is introduced. More details of the metaphor's source are described and their application to human-machine interaction, automation and management of intelligent vehicles sketched. Finally, risks and opportunities to apply the metaphor to technical applications are discussed.

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